SPATIAL THINKING: PRECEPT FOR UNDERSTANDING OPERATIONAL ENVIRONMENTS

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by

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Problem solving modes of thought fall into categories such as critical, creative, systems, and spatial. At present, the U.S. Army lacks a definition and doctrinal references to the spatial mode of thinking. As a result, the Army is underprepared to use spatial concepts to understand operating environments. By comparing the definitions, instruction, advocacy, and maximization of spatial thinking within academia to spatial thinking within Army doctrine and practice, opportunities appear for more efficient problem solving. The Army must define spatial thinking, create a formal program to engage spatial thinking, and identify a proponent organization to maximize its use. By not defining these three things, the Army is missing an opportunity to leverage what is a columnar thought process outside the Army. Defining spatial thinking would bring unity with academia. Implementation would open a universe of academic and training courses that foster spatial thinking skills. Proponency of spatial thinking would amplify the Army voice while working with academia. Maximization of spatial thinking would yield a better institutional understanding about the interrelationship between the environment and the soldier. Moreover, commanders hold a major competitive advantage who spatially understand, visualize, and describe the operating environment faster and in better detail than their adversaries.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

SPATIAL THINKING: PRECEPT TO UNDERSTANDING OPERATIONAL ENVIRONMENTS, by Nathan D. Scott, 72 pages.

Problem solving modes of thought fall into categories such as critical, creative, systems, and spatial. At present, the U.S. Army lacks a definition and doctrinal references to the spatial mode of thinking. As a result, the Army is underprepared to use spatial concepts to understand operating environments. By comparing the definitions, instruction, advocacy, and maximization of spatial thinking within academia to spatial thinking within Army doctrine and practice, opportunities appear for more efficient problem solving. The Army must define spatial thinking, create a formal program to engage spatial thinking, and identify a proponent organization to maximize its use. By not defining these three things, the Army is missing an opportunity to leverage what is a columnar thought process outside the Army. Defining spatial thinking would bring unity with academia. Implementation would open a universe of academic and training courses that foster spatial thinking skills. Proponency of spatial thinking would amplify the Army voice while working with academia. Maximization of spatial thinking would yield a better institutional understanding about the interrelationship between the environment and the soldier. Moreover, commanders hold a major competitive advantage who spatially understand, visualize, and describe the operating environment faster and in better detail than their adversaries.
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ACRONYMS

ADM	Army Design Methodology
ADRP	Army Doctrine and Training Publication
AOC	Army Operating Concept
ATP	Army Techniques Publication
COP	Common Operating Picture
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and education, Personnel, Facilities
GEOINT	Geospatial Intelligence
GIS	Geospatial Information Science or Geospatial Information System(s)
GPS	Global Positioning System
IPB	Intelligence Preparation of the Battlespace
JIPOE	Joint Intelligence Preparation of the Operating Environment
NGA	National Geospatial-Intelligence Agency
NRC	National Research Council
OE	Operating Environment
S2	Army Staff Position–Intelligence Officer
UVD	Understand, Visualize, Describe
WfF	Warfighting Function

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CHAPTER 1

INTRODUCTION

> To look over a battlefield, to take in at the first instance the advantages and disadvantages, is the great quality of a general.[1]
>
> — Chevalier Folard

Spatial thinking is a mode of thought, consisting of space, ways to represent knowledge of space, and the ability to use reason to generate new knowledge.[2] For time immeasurable, geography strongly influenced how armies have fought and won (or lost).[3] The coupling between military success and physical geography, demonstrated over millennia of warfare, is so strong that military geography is a staple at the U.S. Military Academy.[4] What is at the heart of this coupling? Spatial thinking. *Coup d'oeuil*, or the ability to see a battle before it unfolds on the battlefield, is the term given to Chevalier Folard's observation.[5] When a commander visualizes the environment, he/she is creating mental images of the interconnected nature of time and space. He/She is thinking spatially.

Mathematicians think in numbers, linguists in vocal tones (words), and artists in images of feeling. To understand spatial thinking is to understand the nature of how humans organize and describe the world. The ability is innate in everyone. It is the ability of a school girl to understand how she will navigate home from school. It is the visualization of a three dimensional (3D) point cloud representing elevations. It is the ability to describe actions on a military objective, using a map or imagery, during an operations brief. Spatial thinking allows us to describe the world around us, leaping from a 3D mental image to a two dimensional (2D) representation, back to 3D. It enables us to

think about our relationship in space and to describe, in great detail, how that space impacts our interactions.

Like any mode of thinking, be it numerical, artistic, or vocal, spatial thinking requires a medium for expression. The internal mental processing associated with thinking spatially is non-verbal. It exists in the young and old, human and animal. To leap from the mental concept of space, to representation and reason, requires expression. Humans are able to use spoken and written language to express universal concepts of space. This manifests in an ability to draw a crude map on a cave wall (representative, written language). It is the ability to describe navigational directions to a friend coming for dinner (spoken language). Most importantly, it is the ability to relate a written or spoken concept into actions through reason.

The Army's Mission Command doctrine strongly integrates these abilities through the commander's role in the operations process.[6] A commander must be able to understand, visualize, and describe (UVD) the operating environment for his/her subordinates. If these three words are substituted for the three components of spatial thinking: concept of space, representations of space, and reason, then the importance of spatial thinking to a military commander becomes apparent. How this occurs has changed over time, going from crude drawing in the sand to 3D visuals of the battlefield. With a link established between spatial thinking and Mission Command, it is possible to examine what spatial thinking does to empower leaders.

The Army of 2025 and beyond must be able to operate in an increasingly complex world.[7] To do this, the Army needs an accurate language to describe complex environments. As leaders develop an understanding of them, they must have a vocabulary

to articulate that visualized understanding to subordinates. Spatial thinking can provide a language to make this possible. This is one mode of thinking, when paired with systems, creative, and critical thinking, which can assist the Army to win in a complex world.

Critical thinking, creative thinking, and systems thinking are present in doctrine. Unfortunately, spatial thinking, as an expressed and discussed mode of thinking, is neglected in current Army doctrine. Its essence is present, as described through Mission Command in UVD, but does not appear as a specified mode of thought. By neglecting spatial thinking, the Army is losing an opportunity between its ability to understand and visualize the world and an ability to describe the complex world it must operate in.

To properly frame a question that addresses this problem there are a number of issues that must be addressed. One issue is the Army's (and DoD) perspectives on the utility of spatial thinking, as embodied through doctrine, instruction, and action. Another issue is the time and energy required to foster spatial thinking, specifically how the U.S. population treats spatial education in academic settings. Yet another issue is the ability for academia to support the military with subjects that foster spatial thinking, such as geography, biology, physics and astronomy. Each of these issues build the capacity to think spatially. The final issue is the gap between current capability and future capability, relative to threats that the U.S. Army may face.

Each of these issues stitch together to become components of one larger problem statement: Army doctrine does not recognize spatial thinking as a mode of thought that supports Mission Command through organized analysis of operating environments.[8] It is from this overarching problem statement that one can analyze some contributing factors.

In order to answer this problem, however, one must ask a question, embodied within a research question, which will help to answer the overall question.

Research Question

What are the lost opportunities for the U.S. Army if doctrine does not utilize spatial thinking to help describe a complex operating environment? From this question sub-questions were derived, each a problem in their own right. Taken together, the answers to these questions will help to answer the research question.

Answering this question directly will require asking and answering additional questions. Specifically, we must ask:

1. Does the Army define spatial thinking?
2. How does the Army instruct spatial thinking concepts?
3. Does the Army advocate for spatial thinking?

From those answers come an additional question:

4. How does Army maximize the use of spatial thinking?

Finally, from answers to that question we can begin to answer the primary research question: What are the lost opportunities for the U.S. Army if doctrine does not utilize spatial thinking to help describe a complex operating environment?

Methodology

This study will use content analysis as a research methodology. The primary means in which this will occur is by comparing U.S. Army doctrinal texts to documents and studies produced by academia. The intent is to draw qualitative information, similarities and differences, between what current research indicates and what doctrine

prescribes from the field of spatial thinking. By understanding what doctrine and academia say about spatial thinking, comparing them against each other, lost opportunities for the U.S. Army will be identified.

The Joint Intelligence Preparation of the Operating Environment[9] (JIPOE) (see figure 1) and the Commander's Role in the Operations Process (figures 2 and 3)[10] help depict how spatial thinking underpins the interrelated nature of Operating Environment (OE) visualization. Understanding, visualizing, and describing (UVD), as part of the commander's role in operations, helps to emphasize the importance of spatial thinking to all levels of operations.

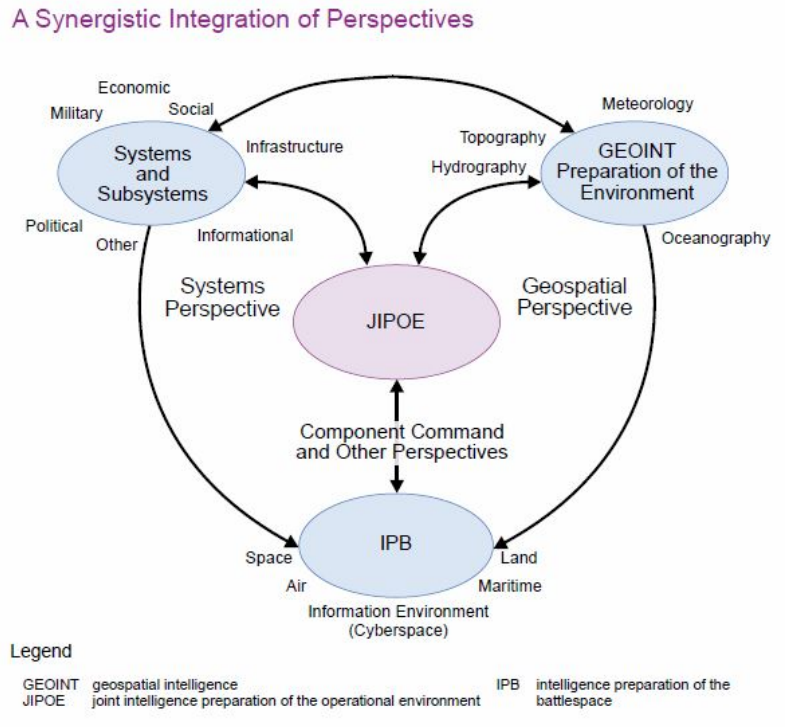

Figure 1. A Synergistic Integration of Perspectives

Source: Joint Chiefs of Staff, Joint Publication (JP) 2-01.3, *Joint Intelligence Preparation of the Operational Environment* (Washington, DC: Government Printing Office, 2014), I-6.

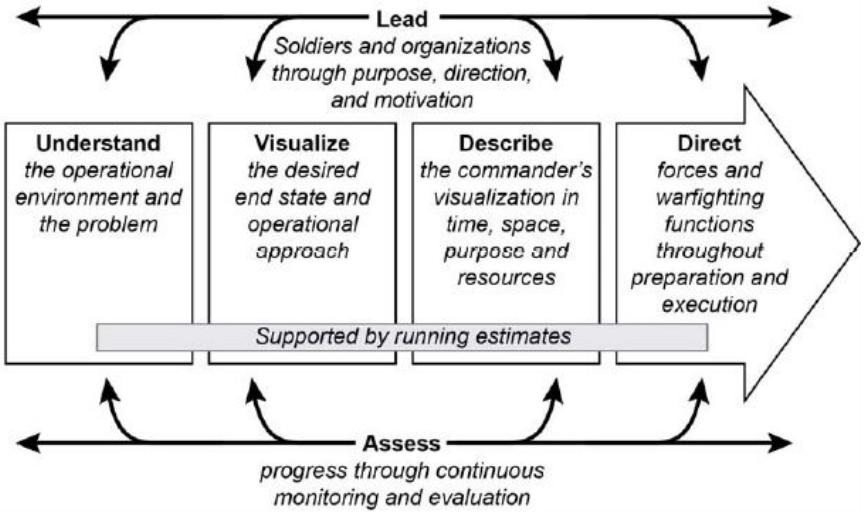

Figure 2. The Commander's Role in the Operations Process

Source: Department of the Army, Army Doctrine Reference Publication (ADRP) 5-0, *The Operations Process* (Washington, DC: Government Printing Office, 2012), 1-3.

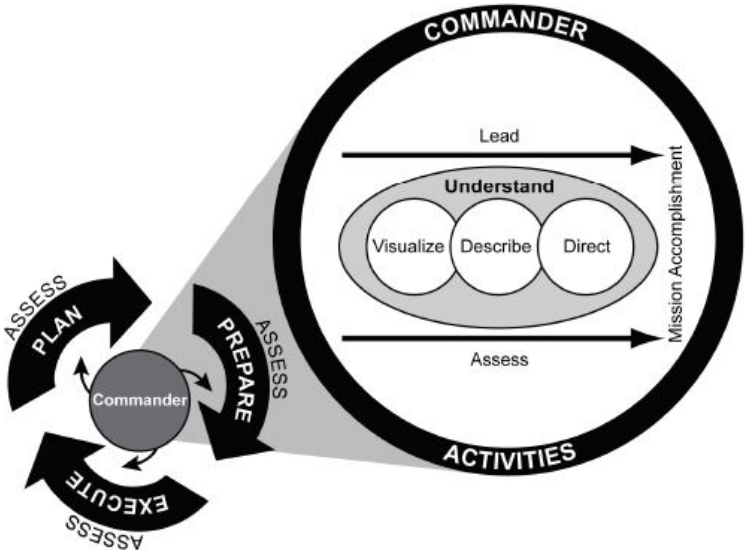

Figure 3. The Operations Process

Source: Department of the Army, Army Doctrine Reference Publication (ADRP) 5-0, *The Operations Process* (Washington, DC: Government Printing Office, 2012), 1-2.

Comparing doctrine and academic literature to models helps identify how spatial thinking enables commanders and staffs to describe OEs. These models will help provide context for sub-questions 1-3. From there, as a component of OE visualization, understanding the Army's use of spatial thinking will help to answer sub question 4. Finally, the answers to all of these questions build to answer the primary question and address the overall problem statement.

Assumptions

For this study, a number of assumptions are made and assumed to be true. The first is Waldo Tobler's first law of Geography, "Everything is related to everything else, but near things are more related than distant things."[11] This relates to the idea that spatial thinking is ever pervasive, since it is the language used to describe environmental relationships. In other words, spatial thinking is how we understand Tobler's law when it relates to things in the environment. Next, humans' ability to think spatially is a requirement to implement spatial thinking into an enduring capability. This assumption then leads into another assumption, that given training and experience Soldiers are able to gain the ability to think spatially. Finally, the study assumes that there is net positive gain out of the ability to think spatially. Specifically, if Soldiers and commanders can understand, visualize, and describe the OE in more detail and faster than an adversary, that it will give them an advantage on the battlefield.

Definition of Terms

Spatial thinking requires the use of unique terms that typically are not found outside of geographic practitioners. Additionally, some terms may illicit multiple

connotations, yet mean specific things within the context of spatial thought. The below terms are not meant to be all encompassing, but rather serve as a starting point for spatial vocabulary.

Common Operating Picture (COP). A common operating picture is an integrated portrayal of friendly, neutral, and adversary forces against a foundation of geospatial information.[12] A COP is a tool of representation intended to help portray reasoning. A COP takes the spatial environment as it is known, represents it based on what a unit wants to see, and enables humans to generate reasoning. The COP is a current visualization, so everyone sees things the same way, of the spatial understanding that describes the OE. Also sharing similar meaning to a COP are *The Army Map* and NGA's *Map of the World*. Each seeks to portray the OE in a standard way for all people using it.

Distance. The degree or amount of separation between two or more points, lines, surfaces, or objects.[13] The U.S. Army typically associates distance with an amount of effort required to overcome a distance. The time, energy, money, or general effort required to move people or things from one place to another is cost distance, which accounts for enemy encounters, the effects of terrain, physical or moral strain, and logistical requirements (wear/tear/fuel).[14] Another way the U.S. Army associates distance with action is risk distance, which is the distance to a perceived, theoretical point in time and space beyond which it would be imprudent, irresponsible, or self-destructive to proceed in some activity.[15]Risk distance and cost distance are examples of using spatial thinking while planning or executing a military operation.

GEOINT. Geospatial intelligence is the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and

geographically referenced activities on the Earth. GEOINT consists of imagery, imagery intelligence, and geospatial information.[16]

Geospatial. Relating to or denoting data that is associated with a particular location.[17] It is important to separate geospatial from spatial. Spatial refers to things in relationship to other things, and are inherently not "geo"spatial. This is identified because the geo in geospatial is the link between an existing spatial relationship and a specific location on the Earth.

Intelligence Preparation of the Battlefield/Battlespace (IPB). An Army process that the S2 staff uses to assist a commander to understand the OE. This term relates to the series of steps and methods that help to create understanding of operational environments for U.S. Army echelons. IPB results in many discreet outputs, where the intent is to provide a holistic understanding of the environment in which an echelon is conducting military operations.[18]

Joint Intelligence Preparation of the Operational Environment (JIPOE). A joint process defined by JP 2-0 as "The continuous process through with the J2 manages the analysis and development of products that help the commander and staff understand the complex and interconnected operating environment."[19]

Mind Map. A term that is typically associated with brainstorming or critical thinking. As defined by the Cambridge English Dictionary, a mind map is "a diagram for organizing information so that it is easier to remember."[20] A mind map, as it relates to spatial thinking, is the "visualize[d] structural shapes in the mind's eye and the ability to rotate, translate, and shear them."[21] A mind map, for spatial thinking, is thus just one's mental model of space before they are replaced by descriptions.

Operating Environment. A composite of the conditions, circumstances, and influences that affect the employment of capabilities and bear on the decisions of the commander. Also called an OE.[22]

Reasoning. The process through which one is able to describe thoughts and representations of space. It is the reasoning element that provides the context and the "so what" factor of spatial thinking. Also, it provides a connection to other forms of thought, specifically critical thinking and creative thinking.[23]

Scale. According to Webster's English Dictionary, scale is a "graduated series of scheme or rank or order" or "a proportion between two sets of dimensions."[24] An amalgam of these definitions is the understanding that scale is a representation of spatial relationships that are meaningful to the human mind. Scale exists to help humans work thought the representation element of spatial thinking. Without scale it is nearly impossible to represent complex environmental interactions into something that humans can understand.

Space. Space is the metaphorical area between objects, from the subatomic to the super massive. It can also refer to a specific location within this area of an object. It involves the location, size, direction, distance, separation, connection, shape, pattern, and movement of those objects within this void.[25] Space can be specific, such as a postal address or a GPS coordinate. Space can be generic, such as urban or rural. Space can also be generic and be a link between objects. Spatial thinking uses space to arrange and connect objects, tangible or intangible.[26]

Spatial Cognition. D. R. Montello describes spatial cognition as the study of knowledge and beliefs about spatial properties of objects and events. Spatial cognition is

the ability to understand relationships in space, specifically how they interact with themselves and others. It is the ability to understand location, size, direction, distance, separation, connection, shape, pattern, and movement. Each of these are inherent qualities of an object or qualities of two or more objects to each other.[27]

Spatial Connectedness. As defined by the author, the specific relationship that one object has to one or more other objects. The level of connectedness that one object has with another object is best embodied by Tobler's first law, that close things are more related than far things.[28] Spatial connectedness does imply a relationship, but not necessarily a physical relationship.

Spatial Thinking. A mode of thought, typically associated with geography. Academically, it is defined by Dr. Roger Downs of Penn State University as "a form of thinking based on an amalgam of three elements: concepts of space, tools of representation, and the process of reasoning."[29]

Tools of representation. Ways in which humans articulate the concepts of spatial interrelations to each other. One very common tool is a map. The map can be a piece of paper representing the proximity of objects. A map can also be a digital representation of the same. Another increasingly common tool are geospatial information systems, such as Google Earth. Tools could also include written words. Tools serve as a way to express thoughts about space.[30]

Limitations

Research for this writing will focus on publications from the U.S. military and academic sources. It seeks to focus specifically on the similarities and differences between military and non-military utilization of spatial thinking. The researcher will

endeavor to use pre-established models as a base of common understanding. Where appropriate, the author may suggest changes, but there is no intent to create new models. Testing emerging and theoretical spatial thinking concepts is beyond the scope of this research. To the maximum extent possible, academic reports of testing in support of spatial thinking will be used to demonstrate military utility.

Scope and Delimitations

This study seeks to understand the doctrinal foundation for Army inclusion of spatial thinking during Mission Command and assisted by the Intelligence Warfighting Function. The study will focus on spatial thinking with intelligence and operations doctrine as the basis for common understanding. Spatial thinking will be analyzed in the same context as critical thinking, creative thinking, and systems thinking within doctrine and academia. This research will seek to use spatial thinking as an enabler to help describe interactions within an operating environment. It will focus on education, understanding, and theory.

The study will not describe or research specific technologies or technological capabilities, but will use GIS technology as a broad concept for use when visualizing spatial concepts. Furthermore, this study will not conduct any new scientific studies or attempt to reanalyze completed studies using the same data. It will, however, utilize the published results of prior studies to demonstrate military utility.

Significance of the Study

This study is significant because it will help to identify differences between Army doctrine and academic research, while proposing solutions to address potential lost

opportunities of interest to the U.S. Army. In recent years, academic research concerning spatial thinking is on a trajectory that the U.S. military does not seem to be following. Failure to incorporate new ways to understand complex environments, from a spatial sense, represents a lost opportunity. When the Army neglects opportunities it usually results in monetary costs, or risk to the lives of Soldiers. The results of this study could help drive Doctrine, Organization, Training, Materiel, Leadership and education, Personnel, or Facilities (DOTMLPF) solutions. It could enable junior leaders to provide a more thorough analysis in support of battlefield understanding to better drive operations. This will help to posture the Army with the knowledge and understanding to enable commanders to understand, visualize, and describe increasingly complex operating environment.

Summary and Conclusions

Spatial thinking is necessary for understanding the world and how objects in that world relate to one another. As the U.S. Army moves into a future dominated by information, it will be vital to understand how to give spatial information meaning during problem solving. Academia has increased its awareness and research into the field of spatial thinking over the past 50 years. Meanwhile, the U.S. Army seems to focus less and less on how humans utilize spatial thought and instead focused on technological tools that represent spatial interactions. By reviewing current literature from military and academic sources it might be possible to determine some of the lost opportunities.

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CHAPTER 2

LITERATURE REVIEW

The purpose of this research is to identify the lost opportunities for the U.S. Army if doctrine does not utilize spatial thinking to help describe a complex operating environment. To that end, this literature review is organized into two categories, military and academic, each divided into three subcategories, general, categorical, and specific. It will begin with military literature which provides doctrinal and DoD focused writings, and be followed by academic literature on theory and research. Within each category, military and academic, the review will transition from general knowledge to categorical knowledge to specific knowledge. Many sources could appear at multiple levels, but will be identified here in only one category each.

General Military Literature

Overarching military literature on the nature of spatial thinking is lacking, but by examining two specific sources one can draw out the concept, if not the exact wording. At a strategic level, military literature focuses on a link between the human landscape and the physical landscape. In the current world environment, knowing one requires knowing the other. Rather than specifically identifying spatial thinking, general military literature indicates a necessity to understand the human and physical environments in the contexts of critical and creative thinking.

In their white paper “Strategic Landpower,” Generals Raymond Odierno and James Amos, and Admiral William McRaven identified key actions pertaining to the future of landpower. Specifically, they identified that “the success of future strategic

initiatives and the ability of the U.S. to shape a peaceful and prosperous global environment will rest more and more on our ability to understand, influence, or exert control within the human domain."[1] This context is important because it provides joint understanding that the fundamental interactions between people and the environment will be crucial in future conflict. They continue on to state that "this significance is growing, not diminishing."[2] From a national level, understanding the OE is a certain requirement for future leaders.

Two important points of action were addressed in "Strategic Landpower" that deserve special identification. First, expanding the use of social sciences alongside the physical sciences.[3] This statement insinuates a critical link between human and physical geography (i.e. landscapes). Second, the formulation of strategy and plans will require an integration of our understanding between human and physical objectives.[4] Again, the vision from senior leaders of each land service stress the importance of understanding the links between the physical and human dimensions.

The current U.S. Army Operating Concept (AOC), entitled *Win in a Complex World*, recognizes that human interactions among cities, varying demographics, and complex terrains will be a future norm. To overcome these challenges, it states that "Understanding the technological, geographic, political, and military challenges of the urban environment will require innovative, adaptive leaders."[5] Further, the principle of innovation arises where it is used to describe the "result of critical and creative thinking and the conversion of new ideas into valued outcomes."[6] Like the white paper, the AOC identifies a need for leaders who can think through the complexities of the operating

environment, specifically pertaining to human interactions within the physical environment.

Categorical Military Literature

Categorical Military literature covers the operational level of Army literature. Unlike military strategic literature (general knowledge), some terms surrounding spatial thinking begin to emerge. Two doctrinal documents form the foundation for the introduction of spatial thinking or spatial awareness as a form of cognition.

At the Joint level, JP 2-0, *Joint Intelligence*, introduces the Joint Intelligence Preparation of the Operational Environment (JIPOE) process. In JP 2-01.3, *JIPOE*, the process is further defined, and from here out will be used as the primary source for JIPOE vice JP 2-0 (which simply introduces it). Within JIPOE, a number of concepts hint at the idea that spatial thinking is, or must, occur. Specifically, JIPOE is a "holistic" approach that integrates "Geospatial Preparation of the Environment" with "Intelligence Preparation of the Battlespace" with "Systems and Subsystems".[7] Put another way, JIPOE focuses on systems thinking (systems perspective), critical thinking (IPB–component perspective), and "geo"-spatial thinking (spatial thinking referenced to the Earth), all glued together by creative thinking (holistic perspective). In other words, JIPOE utilizes each element of thinking: critical, creative, system, and spatial thinking.

At the Army level, ADRP 5-0, *The Operations Process*, introduces the commander's role in the operations process.[8] In this model, the commander must understand the OE, visualize an operational approach, describe the visualization in time/space/purpose/resources, and direct execution. Although it doesn't include spatial thinking, it does identify critical and creative thinking as inherent to this process. Spatial

thinking, however, is inherent in the ability to understand the current OE, mentally visualize the transition of it to a desired one, and the ability to describe how to get to the desired conditions. This is an important element of Mission Command which will be discussed later, and is a core component to this research.

Specific Military Literature

At the specific knowledge level, military doctrine lacks references to spatial thinking. It focuses on technical product creation rather than intellectual elements of thought. Doctrine that is lacking specific reference to spatial thinking includes ATP 2-22.7 *Geospatial Intelligence,* ADP 2-0 *Intelligence*, and ADRP 2-0 *Intelligence*.

One document that should reference spatial thinking is ATP 2-33.4 *Intelligence Analysis*. In this manual, critical and creative thinking are introduced as central intellectual capabilities of good analysts. Furthermore, it describes ways and components of critical thinking.[9] Spatial thinking, as an element of thought on par with critical and creative thinking, is completely absent. Additionally, systems thinking, which is present in JP 2-0, is listed under structured analytic techniques as a way of looking at a problem.[10]

In non-doctrinal documents, two recent articles published in 2015 start to identify a need for thinking about the geosciences within a military context. The first article, *A Note on the State of Geography and Geospatial Intelligence Research* by Richard Medina and George Harper of the University of Utah, appeared in the Winter 2015 volume of NGA's *Pathfinder* Magazine.[11] They state that the military GEOINT community has more interest in fostering new technology than it does with understanding fundamental spatial problems.[12] They continue on to identify that the core of human geography is the

understanding of human spatial patterns. Their strongest assertion is that "ignoring the need [for geographical knowledge] will eventually lead to extreme failures in policy."[13]

Dr. Alexander Stewart authored an article titled "Geological-Reasoning Training as Preparation for the 'Thinking Warfighter' in the Next-Generation Military" states that geoscience training is the most useful skill or trade that a Soldier can possess.[14] While his article covers primarily geological knowledge, he purposefully wrote to include all of the geosciences. Critically, he links geoscience training to critical thinking as an important component of how geoscientists approach problems. He did not specifically identify spatial thinking.

General Academic Literature

Academic literature on the nature of spatial thinking, specifically spatial theory, is quite large. Some of the earliest spatial thinking works come from philosophy and move into a modern approach, which is more psychological. General academic literature on spatial thinking covers the psychological aspects of human perception of space. For the sake of utility, most academic literature will be discussed at the categorical and specific levels due to their narrower focus on the application of spatial thinking.

In his 2009 publication *Spatial Thinking*, Gunter Figal credits Edmund Husserl as a pioneering father of spatial philosophy.[15] Figal cites Husserl's 1907 lecture on "Thinking and Space" as a critical point in our understanding of spatiality. Husserl, as a philosopher, reasoned that spatiality is a perception where every view has its own point of view. He further postulated that "place can only be changed by moving elsewhere, and thus [induces] another aspect of what is seen that can come into view."[16] He finally states

that “Thinking and Space” is “kinaesthetic [*sic*]”, or a form of learning that requires physical activity vice learning through lecture or reading.[17]

Using Husserl’s basic descriptions, Figal delves into describing what comprises spatial perception. To him, space is a kinesthetic (physical) interaction in relation to changing perspective.[18] In other words, humans perceive space as a merging of their own movements relative to everything else around them. It is inherently two parts, perception and interaction. It is this merging of two parts that help to define the academic generalized understanding of spatial thinking.

Categorical Academic Literature

At the categorical knowledge level, academia begins to flood modern literature with research and studies on spatial thinking. Each revolve around the core idea that spatial thinking is a learned skill or response to the previously introduced kinesthetic of space. In other words, how do humans learn to interact with space, and from those interactions how are they able to describe them to other humans? This concept of understanding human place in space and the ability to describe space best characterizes the categorical level of knowledge surrounding spatial thinking.

An important piece of current academic literature published on the concept of spatial thinking was produced by the National Research Council (NRC) and is entitled *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*. While sponsored and advanced by the NRC, the work was produced by representatives of over 25 academic universities and institutions. Dr. Rodger Downs was the principal lead (Chair), representing the Penn State University’s Department of Geography. Dr. Downs is considered one of the foremost researchers, advocates, and visionaries of spatial

thinking theory. In *Learning to Think Spatially*, Dr. Downs defined modern spatial thinking, and proposed why and how spatial thinking should be a core component in K-12 education. Tying back in to Husserl's psychological understanding, the NRC defined spatial thinking as a "distinctive form of thinking that is comprised of three components: spatial concepts, spatial tools, and the process of spatial reasoning."[19]

In a similar work from Penn State University, Alexander Klippel wrote *Spatial Information Theory Meets Spatial Thinking: Is Topology the Rosetta Stone of Spatio-Temporal Cognition?* In his article, he postulates that there is a gap between spatial theory and systems (the technology), and human spatial cognition.[20] Furthermore, he argues that because humans are part of the spatial environment (kinesthetic) they must be able to properly understand it in order to articulate methods for improving the theories and systems.[21] In essence, he is stating that the bridge between spatial technology and human spatial understanding must be built through deeper human understanding of spatiality.

Professors in psychology from Florida International University and the University of Chicago wrote a paper called *Children's Spatial Thinking: Does Talk About the Spatial World Matter?* In this article, Shannon Pruden, Susan Levine, and Janellen Huttenlocher used non-verbal tests to demonstrate a relationship between the amount of spatial language a parent can articulate and a child's spatial language.[22] The authors study compared testing results on children, from 46 months old to 14 years old, with their parents.[23]

Another article, "Spotlight on Gersmehl and Gersmehl", written by Adrian Manning for *Geography* magazine highlights points made by Dr. Downs and the NRC

study, and by P. J. and C. A. Gersmehl in a conceptual skills study. Unlike children and spatial language, the article focuses on the use of geospatial information systems (GIS) as a support mechanism for learning to think spatially.[24] He states that the failure to teach GIS at a young age is a "missed opportunity" and hinders spatial thinking.[25] While Manning provides no direct evidence, his assertion is that GIS skills (i.e. the learned ability to manipulate information in a GIS) directly reinforce spatial thinking.

Spatial thinking is not, however, resident in only the realms of geography, psychology, and philosophy. Neuroscientists are also researching how and why the human brain processes spatial information. In "Beyond the Nobel: What Scientists Are Learning About How Your Brain Navigates" Greg Miller wrote about current neurological studies related to navigation.[26] In it, Russell Epstein, a neuroscientist from the University of Pennsylvania discusses how he is studying the methods in which people navigate through space. As part of his study, the participants submitted to navigational testing in unfamiliar urban settings. After the practical navigation testing, the participants underwent an MRI, where Epstein and his research team identified a correlation between the size of the hippocampus and the participant's ability to navigate.[27] This, he suggests, indicates a physiological linkage between the brain's spatial processing center and the ability to interact in space.

Taken in total, categorical academic literature moves from the philosophical manifestation of what comprises space and understanding to the psychological theory of how humans interpret their interactions within space. Most studies revolve around spatial skill testing, such as the ability to navigate between points, and spatial learning during

early life. Some of the above pieces of literature allude to connections between conceptual learning at a young age and demonstrated ability later in life.

Specific Academic Literature

With this level of literature there is a shift between the more esoteric understanding of spatial thinking at the philosophical (general) level and the more practical application at the specific level. While even literature at this level reflects the philosophical underpinnings of spatial thinking, the focus is shifted to the skills, capabilities, and physical enablers that comprise spatial application.

In addition to Dr. Downs from Penn State University, Daniel R. Montello from the University of California (UC) Santa Barbra is an important figure in modern spatial thinking research. Over the past thirty years, he authored numerous books, articles, and reviews on the nature of spatial thinking and cognition. His book *Space in Mind: Concepts for Spatial Learning and Education* provides an excellent summary of why spatial education is important. He begins by simply defining concepts, moving into their importance, and concluding with ways to improve spatial skills.[28] In *Functions and Applications of Spatial Cognition*, D. R. Montello identifies six tasks that require significant spatial thinking. While most of the tasks are obvious, like navigation, tasks like “using spatial language” and “imagining places and reasoning with mental nodes” are not unless one has a founding in spatial education.[29]

In *Spatial Cognition*, Montello explains spatial cognition; the ways in which humans develop knowledge and beliefs about spatial properties of objects.[30] He specifically identifies location, size, distance, direction, separation, connection, shape, pattern, and movement as important spatial cognitive properties.[31] Using these, Montello

further goes on to describe the importance that geography has in supporting spatial cognitive development. This culminates in a theory that humans develop spatial knowledge, through spatial thinking utilizing the elements of spatial cognition, by progressing through three thought stages.

In stage one, landmark knowledge develops as one is able to provide spatial understanding in relationship to big "landmark" things in the environment.[32] From there, humans develop route knowledge, where understood and visualized knowledge can be passed on through specific distance, direction and description of the environment.[33] Once one possesses route knowledge, survey level knowledge begins to develop. With survey level knowledge the entire frame of the present environment can be described in intimate detail.[34] A good example is an ability to know, represent, and describe where all the fuel stations are in X location that serve dark roast coffee with pumpkin spice creamer. Survey level knowledge is developed over time through significant interaction with one's surroundings.

Beyond just specific academic theory, academia has recently conducted studies to identify links between spatial thinking ability and environmental interaction. In 2003, Jongwon Lee and Robert Bednarz conducted a study to see if there was a relationship between college students who took spatially enabling classes (remote sensing, cartography, GIS) and students who did not take those classes.[35] They identified a positive correlation of .578 (out of -1 to +1), tracking the spatially trained students as exhibiting better spatial thinking abilities than their peers.[36]

In 2015, Vanika Verma of Texas State University's Department of Geography authored an article on research that followed the methods of the Lee-Bednarz study. Of

interest is the concept that geospatial thinking is a subset of spatial thinking that uses Earth space to frame problems, identify answers, and provide solutions utilizing the three components of spatial thinking.[37]

Joseph Stromberg authored an article on the use of GPS and navigation.[38] In it he interviewed and cited many neuroscience researchers studying how the brain processes spatial stimuli from human senses. Temple University psychologist Nora Newcomb stated that with GPS "you are just listening to a voice" and not otherwise interacting with your surrounding environment.[39] In this case, that interaction is your position relative to everything else around you as you drive between two locations.[40] Veronique Bohbot of McGill University states that with GPS navigation you are "not actually learning about the environment, but following a sequence of steps."[41] Most importantly, Newcomb states that people who are bad navigators (in the absence of GPS) are usually good memorizers (of directions) and do not exhibit good navigational abilities, namely the ability to create mental maps that relate one route to another.[42] She goes further in Stromberg's interview to state, based on her research, that there is a physiological link between the size of the brain's hippocampus and the ability to create good mental maps.[43]

Taken in total, specific academic literature seeks to identify physical manifestations of spatial thinking. What humans can do to foster spatial thinking is the primary qualitative process, through spatial education and practical application. On the quantitative front, academic research, specifically within neuroscience, seeks to understand how the brain processes spatial information. As previously identified through these specific literature reviews, current postulation states there is a strong link between spatial education and spatial abilities. Through spatial education and reinforcing

application, the brain develops a physiological link between understanding and capability.

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[1] General Raymond T. Odierno, General James F. Amos, and Admiral William H. McRaven, "Strategic Landpower: Winning the Clash of Wills," 2015, 5.

[2] Ibid.

[3] Ibid., 2.

[4] Ibid., 6.

[5] Department of the Army, TRADOC Pamphlet 525-3-1, 12.

[6] Ibid., 22.

[7] Joint Chiefs of Staff, JP 2-0, I–6.

[8] Department of the Army, ADRP 5-0, 11.

[9] Department of the Army, ATP 2-33.4, 2–2, 2–3.

[10] Ibid., 3–1.

[11] Richard M. Medina and George F. Hepner, "A Note on the State of Geography and Geospatial Intelligence Research," *NGA Pathfinder* (March 2015): 8.

[12] Ibid.

[13] Ibid.

[14] Alexander K. Stewart, "Geological-Reasoning Training as Preparation for the 'Thinking Warfighter' in the Next-Generation Military," *Journal of Military and Strategic Studies* 16, no. 1 (2015): 5.

[15] Günter Figal, "Spatial Thinking," *Research in Phenomenology* 39, no. 3 (January 2009): 339.

[16] Ibid.

[17] Ibid.

[18] Ibid.

[19] U.S. National Research Council, *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, ix.

[20] Alexander Klippel, "Spatial Information Theory Meets Spatial Thinking: Is Topology the Rosetta Stone of Spatio-Temporal Cognition?," *Annals of the Association of American Geographers* 102, no. 6 (2012): 1311.

[21] Ibid.

[22] Shannon M. Pruden, Susan C. Levine, and Janellen Huttenlocher, "Children's Spatial Thinking: Does Talk about the Spatial World Matter?," *Developmental Science* 14, no. 6 (November 2011): 1417, doi:10.1111/j.1467-7687.2011.01088.x.

[23] Ibid., 1418.

[24] Adrian Manning, "Spotlight on Gersmehl and Gersmehls' Wanted: A Concise List of Spatial Thinking Skills," *Geography* 99, no. 2 (Summer 2014): 109.

[25] Ibid.

[26] Greg Miller, "Beyond the Nobel: What Scientists Are Learning About How Your Brain Navigates," Wired.com, 6 October 2014, accessed 22 November 2015, http://www.wired.com/2014/10/map-brain-navigation/.

[27] Ibid.

[28] Daniel R. Montello, Karl Grossner, and Donald G. Janelle, "Concepts for Spatial Learning and Education: An Introduction," in *Space in Mind: Concepts for Spatial Learning in Education* (Cambridge, MA: MIT Press, 2014), 3–29.

[29] Daniel R. Montello and M. Raubal, "Functions and Applications of Spatial Cognition," in *Handbook of Spatial Cognition*, ed. D. Waller and L. Nadel (Washington, DC: American Psychological Association, 2012), 251.

[30] Montello, "Spatial Cognition," 14771.

[31] Ibid.

[32] Ibid., 14772.

[33] Ibid.

[34] Ibid.

[35] Lee and Bednarz, "Effects of GIS Learning on Spatial Thinking," 184.

[36] Ibid., 187.

[37] Kanika Verma, "Influence of Academic Variables on Geospatial Skills of Undergraduate Students: An Exploratory Study," *The Geographical Bulletin* 56, no. 1 (2015): 41.

[38] Joseph Stromberg, “Is GPS Ruining Our Ability to Navigate for Ourselves?,” Vox, 2 September 2015, accessed 22 November 2015, http://www.vox.com/2015/9/2/9242049/gps-maps-navigation.

[39] Ibid.

[40] Ibid.

[41] Ibid.

[42] Ibid.

[43] Ibid.

CHAPTER 3

RESEARCH METHODOLOGY

This study utilized content analysis to compare military doctrinal writings to academic research writings. The intent was to identify qualitative information–the similarities and differences–between what current academic research indicates and what doctrine prescribes in the field of spatial thinking. By comparing and contrasting the two, lost opportunities surfaced.

Content Analysis is a research methodology through which information is interpreted to make inferences through systematic evaluation of reference material.[1] Through the interpretation process, analytical inferences turn descriptive information into useful data for comparative analysis. This methodology was chosen because there is a large volume of descriptive information about spatial thinking produced by academia suitable for comparison against Army writing. U.S. Army doctrine similarly offers sources of descriptive information about problem solving processes, outcomes, and future desires. This approach optimizes similarly descriptive information about spatial thinking concepts between military and academic sources.

The information collection process consisted of specific academic research into spatial thinking past and present. The focus included research into the psychology of thinking, current neuroscience experiments, and applications within a learning environment. Collected information was coded into general, categorical, and specific literature. Once a baseline of academic research was collected, research into similar military writings began. Army literature was divided into general, categorical, and

specific categories. Each category assisted with the analysis process, allowing for general inferences as well as specific examples.

The analysis (see figure 4) began by comparing the definition of spatial thinking in academic writing and military doctrine. Next, the study focused on the instruction of spatial thinking for work and daily use. Third, the research focused on academic and military advocacy, specifically the proponent fields that would use spatial thinking the most. During these comparisons, the focus was on the use of spatial thinking to enable a commander to describe OEs as part of Mission Command. Finally, the study analyzed settings in which the Army could maximize the use of spatial thinking. During this process, the primary and supporting research questions are addressed, specifically:

1. Does the Army define spatial thinking? Has language, or taxonomy, of spatial thinking within doctrine changed over time?
2. How does the Army instruct spatial thinking? What are the spatial products, processes, or actions that the Army teaches or should teach?
3. Does the Army advocate for spatial thinking? Which Warfighting Function or Center of Excellence is the lead or proponent for spatial thinking?
4. How does the Army maximize the use of spatial thinking?

With answers to these questions, it was possible to answer the primary research question: What are the lost opportunities for the U.S. Army if doctrine does not utilize spatial thinking to help describe a complex operating environment?

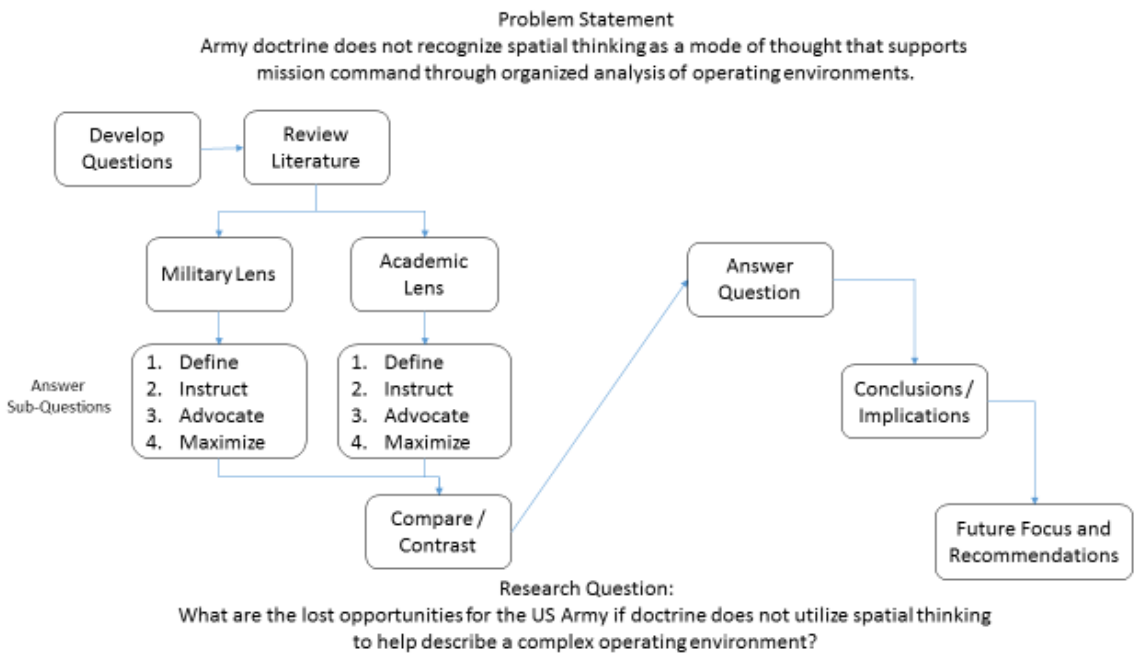

Figure 4. Methodology Workflow

Source: Author's illustration.

Possible biases in this process arose from the author's background. Specifically, the author has supporting experiences in both the geosciences and military operations. By utilizing specific examples, confined to clear categories, this bias was hopefully removed. An additional bias came from the availability of literature. Academic literature was easily available in large volume. Army literature was difficult to find on the core topic. This resulted in an assessment of intent and meaning behind Army information that was not explicit in doctrine. It is possible this approach gave meaning where none was intended.

Using content analysis to compare spatial thinking within the Army and academia yielded important insights. Each piece of information helped to answer the supporting questions through a qualitative comparison of similarities and differences. With this

information, important opportunities were identified for the Army. These lost opportunities became recommendations for the Army to implement in the future.

[1] University of Georgia, "Content Analysis as a Research Technique," *Research and Methodology* (2012), accessed 14 April 2016, https://www.terry.uga.edu/management/contentanalysis/research/.

CHAPTER 4

ANALYSIS

Definitions

How does the Army define spatial thinking? Simply stated, it does not define it. ADRP 1-02, *Terms and Military Symbols,* contains only geospatial references. Each of these definitions reference technical capabilities or products, not a mode of thinking.[1] Furthermore, ADRP 1-02 contains the word "thinking" only three times. One of these instances, contained within the definition for Army Design Methodology (ADM), references creative and critical thinking but not spatial thinking. ADM does, however, contain the essence of spatial thinking by "applying . . . thinking to understand, visualize, and describe unfamiliar problems."[2] To overcome the Army's lack of a definition, one must seek the Army's unstated essence of spatial thinking as it relates to the academic definition. From there it is possible to define spatial thinking in Army parlance by identifying what is desired but not stated.

Academia defines spatial thinking as a mode of thinking consisting of space, ways to represent knowledge of space, and the ability to use reason to generate new knowledge.[3] These three components of the academic definition are similar to the three Army elements of understand, visualize, and describe. Understanding the environment in which a unit is operating carries a similar intent as understanding the space in which objects interact. Visualizing an operating environment, either mentally, on paper, or with a computer carries a similar meaning to tool utilization to represent spatial (e.g. environmental) interactions. Describing the previous components to subordinate commanders and the staff carries a similar intent as conveying new knowledge generated

out of reason. Due to these similarities, the Army concept of UVD is able to convey a meaning similar to the academic definition of spatial thinking.

An Army commander's ability to understand, visualize, and describe an OE is a critical role within Mission Command. These three words, with the same inherent meaning, appear in numerous doctrinal locations, such as ADRP 1-02, ADRP 5-0, ATP 2-01.3. A less exacting word pairing, simply "describing the OE" occurs in ATP 2-33.4, JP 2-01.3, and JP 2-03. Each time these word pairings are used the intent is for a commander and a staff to support an understanding of the world around them. If the academic definition of spatial thinking is comprised of thinking about space, representing space and reasoning about space, and the Army's intent is to understand, visualize, and describe space, then the conceptual end state is in harmony. Thus the Army does a good job of defining spatial thinking without explicitly acknowledging that it exists.

When applying UVD as a description of spatial thinking, it is useful to ask how this language has changed, if at all, over recent history. Spatial thinking exists as a mode of thought to support environmental (spatial) understanding. As a result of its linguistic focus to convey meaning (describe), spatial thinking uses a set of common words. A Google search yields a number of spatial-related words. According to Merriam-Webster, spatial is a term used to describe the parameters of objects in space.[4] Following this definition, the most common spatial words are: distance, over, under, between, apart, together, around, near, far, big, and small.[5]

Spatial thinking manifests in everyday activities through descriptions of relationships between objects. For example, Sally is five feet from Sam (distance), the roof is over my head (directionality), or Frank is bigger than Jack (size). Description of

relationships, the describe in UVD and reason in academia, is what makes spatial thinking powerful. One of the most common spatial words in ordinary language is distance. To understand the relationship between the word distance and its power for description, one can look at its use within doctrine.

Webster's defines distance as "the amount of space between two places or things; a point or place that is far away from another point or place."[6] The Army does not independently define distance, but within ADRP 1-02 distance is used consistently with the dictionary definition. Additionally, FM 3-25.26 *Map Reading and Land Navigation*, supports the dictionary's contemporary usage.[7] Distance works well as a spatial word due to its relatively static meaning over time, and its use as a noun vice a preposition. Other spatial words, such as: over, next to, beyond, or within–prepositions–can have other descriptive meanings that do not always have spatial connotation.

Spatial language is most useful when coupled with operational actions that use it to describe conditions in the OE. For example, an enemy force of 100 soldiers (size) is fortified on top (directionality) of a mountain 50 Km (distance) from our current position. Another example is U.S. forces will cross (directionality) 100 Km (distance) of open (proximity), barren desert to attack an enemy force fortified within (directionality) the city. These examples helps to explain the synchronization between UVD and a commander, as he/she leads the operations process. To gage how the Army has altered it use of spatial language for operations one can compare the frequency of the word distance, as a descriptor for a spatial relationship similar to the above examples, in doctrine over recent history. Table 1 below lists the publication and the number of times distance was used describing Army operations.

Table 1. Occurrence of Distance in Army Operations Doctrine

Occurrence of *Distance* In Operations Doctrine

Publication Title	Year	Word Count	Page Count	Density
FM 100-5 *Operations*	1939	10	81	12%
FM 100-5 *Operations*	1949	29	150	19%
FM 100-5 *Operations*	1954	42	274	15%
FM 100-5 *Operations*	1968	4	47	9%
FM 100-5 *Operations*	1976	6	69	9%
FM 100-5 *Operations*	1982	1	51	2%
FM 100-5 *Operations*	1993	13	163	8%
FM 3-0 *Operations*	2001	17	318	5%
FM 3-0 *Operations*	2008	57	220	26%
ADRP 3-0 *Unified Land Operations*	2012	29	76	38%

Source: Author generated chart.

The density differences may not seem significant, however they could indicate a subtle mental shift in the understanding of how spatial relationships, distance specifically, effect operations during a major conflict. The intimate knowledge gained by Soldiers about the spatial embodiment of distance during wartime might begin to manifest within doctrine as an attempt to better describe its impacts on operations. This would be a convenient explanation for the bump in the use of distance in operations doctrine following WWI, Desert Storm, and Operations Iraqi Freedom and Enduring Freedom. However, this did not occur in all post war scenarios, such as Vietnam. Another explanation could be that conventional conflict is better understood within the Army, and as such fits closely with the ability to conduct good UVD by a commander. Unconventional conflicts, like Vietnam and OIF/OEF, are usually less understood, at least initially, and thus may hinder good UVD. Later when the doctrine was written, the

ability to describe the impact of distance on operations might be hampered by the prior ability to understand the environment.

Spatial relationships are identified in this analysis through the use of distance as a descriptor, and is the last component of spatial thinking. The conclusion is that by arriving at the third component, the other two must have existed in thinking first. In other words, the use of distance in doctrine helps to indicate an increased use of the entire spatial thinking process.

The Army and academic definition of spatial thinking appears to be similar. Academia clearly defines spatial thinking, as published by the NRC. The Army has no written definition of spatial thinking, but contains similar language within the Mission Command process, understanding, visualizing, and describing an operating environment. While the meaning behind the language is very similar, the definitions are not. This helps to underscore the necessity for a common definition of spatial thinking within the Army.

Instruction

Both the Army and academia must be able to instruct spatial thinking, like any subject, if people are to use it. Instruction is the action or process of teaching.[8] The Army and academia instruct spatial thinking through courses that teach it. For this analysis, instruction will refer to written instructions in doctrine as well as classes that teach spatial thinking and its enabling actions (such as a 3-hour lesson as part of the Senior Leader Course).

A web search for “spatial thinking courses” yields dozens of listings from academic institutions. Civilian institutions, like Penn State University, the University of Redlands, UC-Santa Barbara, Central Michigan, and others, offer classes on spatial

thinking, either as a standalone elective or as part of structured reinforcement in a discipline. These institutions instruct spatial thinking courses as part of a program to incorporate spatial thinking more broadly into the curriculum. For example, Penn State University instructs spatial thinking through a specialized class, "Critical Geospatial Thinking", and as components of its other Earth Sciences courses.[9] Since the Army's UVD is congruent with the academic definition of spatial thinking, then how does the Army instruct spatial thinking?

The Army can look at geospatial intelligence (GEOINT) and geospatial engineering as military sources for instruction in spatial thinking. The geosciences, like physics and astronomy, require it. Geospatially trained Soldiers receive spatial thinking skills though their technical training. By digging into the instruction that these Soldiers receive, it might be possible to infer how the Army instructs these skills.

The Army Training and Requirements Resource System (ATRRS) does not list a specific course in spatial thinking.[10] It does, however, list many courses in supportive geoscience fields, specifically: Geospatial Engineering Technician, Geospatial Engineer, and Geospatial Intelligence Analyst courses each with a basic, advanced, and senior level of instruction. These nine separate courses represent official Army instruction that has a direct relationship to spatial thinking.

Beginning with the six engineering courses, none of the ATRRS descriptions identify spatial thinking as a topic or point of instruction for the class.[11] Embedded within the topics, however, are technical tasks that help to support it. Specific tasks include the creation of geospatial information (data), management of geospatial databases, and providing geospatial engineering support to full spectrum operations.[12] Each of these

points of instruction help to generate spatial skills, specifically creating digital understanding (data) for an OE, using tools of representation to generate visualizations, and describing the visualizations for commanders in support of operations. Despite not offering specific training on spatial thinking as a topic, geospatial engineers learn skills that are part of the process.

GEOINT Analysis receive training on the same GIS tasks as geospatial engineers. This leads GEOINT Soldiers to possess many of the same spatial thinking skills as geospatial engineers. The primary differences are with each's contribution to the UVD process. Engineers primarily create and visualize data while analysist visualize and describe new information. Like geospatial engineers, GEOINT analysts do not receive specific instruction on spatial thinking as a mode of thought.

During the NRC's research, GIS was identified as a contributing field to spatial thinking.[13] The focus on GIS training for geospatial engineers and GEOINT analysts helps to explain how and why those Soldiers, and the Army, can foster spatial thinking without knowing it. If the Army is then indirectly instructing it through technical GIS training, where else might it be taught?

Another location is within the Intelligence Preparation of the Battlespace (IPB) process. IPB is a four step process which seeks to define the environment, describe environmental effects, evaluate an adversary, and determine possible adversary actions.[14] The intent of IPB is to gain an understanding of the OE and how an enemy will act within it. IPB should, in practice, foster spatial thinking skills similar to those fostered by GIS by defining the OE in step 1 and describing the OE in step 2.[15] Within the intelligence WfF, spatial thinking can assist the IPB process by mentally equipping analysts to

describe OEs. As with the geospatial engineer and GEOINT analyst courses, it is generated through supportive skills rather than as a specific topic.

Yet another example of instruction is land navigation. The Army teaches it to every new Soldier, it is reinforced through periodic training, and assessed through activities such as Expert Infantry Badge testing. Arguably one of the core reasons why humans think spatially is for navigation. Getting from one place to another uses at least two components of spatial thinking, understanding space and representing it somehow. In land navigation this is usually looking at a map, finding out where one is currently and where one needs to go. This is understanding space. Cognitively one then decides how best to go from current location to future location. If one is operating individually, there may be no need to describe or articulate reason to others about space, as would be required if working as a team or unit.

Navigation is intensively spatial, so much so that continual instruction and use of navigation skills is linked to increases in brain size.[16] To note, navigation is not taking rote directions and copying them, although use of said directions may initially enable spatial awareness. Navigational capability grows when one is using his or her understanding of the environment to move independent from outside dictation.

As with academia (civil engineering construction, geographic analysis, astronomical measurements, etc.), there are a number of actions that require spatial thinking in the military. It is thus that the best way the Army instructs spatial thinking, while indirectly, is through land navigation because it is taught to every Soldier. Specialized training to geospatial Soldiers represents a small cohort of the Army. While

beneficial, the small number limits the impact and range of overall spatial thinking support to the Army.

The difference between Army and academic instruction is the Army's apparent lack of specific spatial thinking courses. There are positive skill enablers, such as GIS, IPB, and land navigation, but nothing that specifically instructs spatial thinking as a mode of mental thought. In some ways this is analogous to past academic experiences. Scholars and scientists used spatial thinking in their work, but were ignorant to its presence in the thought process. If the current Army approach is the same as past academic approaches, present but unknown, then there is a lost opportunity by not intentionally providing specific and wide spread instructional training on spatial thinking and its supportive skills.

Advocacy

Webster's dictionary defines an advocate as "one that defends or maintains a cause or proposal."[17] In academia, advocacy is driven by people deeply interested in fostering new thoughts and ideas. The most recent embodiment of this came from the National Research Council's book, *Learning to Think Spatially* which united those with a background and interest in spatial thinking and psychological cognition.[18] The NRC's work represents the most current single proponent organization for spatial thinking.

As a group, academia continues to have vocal advocates for the advancement of spatial thinking concepts, such as Dr. Roger Downs, D. R. Montello, Phillip and Carol Gersmehl, and Alexander Klippel. These researchers are documenting how the brain processes relationships between objects in space in an effort to foster awareness for spatial thinking's influence on problem solving.[19] Psychologists continue to study how

humans make sense of neurological stimuli through cognitive processes, whereby one understands and is able to create meaning from those thoughts. Geographers, biologists, astronomers, anthropologists, and other scientific professionals then utilize spatial vocabulary to articulate descriptions based on reason. To transform a military term, this is a whole of academia approach. It is advocacy through a confederation of academic institutions and professions speaking with one voice.

If the Army lacks a clear definition and does not formally implement or instruct spatial thinking, then does the Army have an advocate for spatial thinking? Around the 2009 timeframe, the Army underwent internal discussions concerning what WfF would be the chief proponent of geospatial content. The conclusion is that the Intelligence WfF oversees geospatial information exploitation for intelligence purposes and Engineers, under the Movement and Maneuver WfF, oversees geospatial information creation and terrain analysis. In some ways this was a continuation of the status quo: topographic engineers made the map products, and intelligence analysts used those products. By dividing, not unifying spatial thinking tasks, there is no current Army advocate for spatial thinking.

A lost opportunity between Army and academic advocacy for spatial thinking does not seem to exist. Specifically, academia appears to be making an advocate (via the NRC) but lacks a functioning framework, and the Army lacks an advocate but has the framework to create one. If one were to create a hypothetical Army advocate, then it is possible to imagine it as a sole entity within a larger organization. It could publish doctrine and develop instruction, through courses and enabling tasks, across the force.

The Army has successfully used this model for many new programs over recent history, critical thinking being one example.

Maximizing Spatial Thinking

To this point, the identification of a definition, an instructional program, and an established advocate for spatial thinking are either present or not present. More difficult to describe is how the Army chooses to maximize the use of spatial thinking. According to Webster's dictionary, maximizing is "using something in a way that it will get the best result."[20] To maximize spatial thinking then is to use it in a way so that it will improve the Army. By this metric anything could suffice. To be more specific, maximization requires the Army to use each of the three components of spatial thinking to achieve a better result than it could without them.

Academia maximizes spatial thinking within the scientific and visual art fields. The first component of it can be seen at work within early philosophy and psychology.[21] The fields of astronomy and physics seek to describe the motion of objects through space. Early philosophy sought to understand human interactions in space. In the second component, each discipline represents space differently. Philosophers and psychologists use words as tools, astronomers and physicists use mathematics, geographers use maps. Through each discipline's questioning of spatial interactions and the representation of meaning through words, pictures, or numbers, the third component, reason, yields new meaning. The NRC study opens using an example of how biologists, seeking to understand the structure of DNA, used X-rays to determine the double helix shape.[22] While stating that all academia maximizes spatial thinking may be a stretch, most scientific disciplines incorporate each component of spatial thinking.

Going a step further, in academia there is a trend toward integrating the strengths of geography into other academic disciplines. An example includes a shared interest between mathematicians describing the area under a curve (i.e. calculus integrals) and geographers identifying the field of view between two points (i.e. a view shed). Future academic maximization of spatial thinking will be a result of cross discipline problem solving. Technology is assisting by filling in a gap between mental understanding and verbal or written articulation. This is most prominently displayed through the use of GIS to speed up spatial visualizations.[23]

By looking at military problem solving it is possible to identify examples of the Army maximizing spatial thinking. The first component, understanding space, is similar to the first step of IPB, define the operational environment. As knowledge of the OE develops, the commander and staff gain an understanding of the spatial interactions. One way to focus this effort toward spatial thinking is to ask probing "where" questions, such as: where are the trails, where are the banks, or where are the crime hotspots? Just as this step is designed to gather relational information, the concept of space is designed to understand object relationships in the environment. Procedurally, the Army has a process to maximize this component. Is this occurring efficiently across the force if only geospatial Soldiers are defining the operating environment? There is no clear answer to this, but since UVD is a commander responsibility, assisted by the entire staff, then it is unlikely that everyone is fully utilizing the first component of spatial thinking.

The second component of spatial thinking requires the use of tools to represent meaning. The Army has a number of examples of integrating visualization tools into the problem solving process. A GIS similar to Google Earth, regardless of the platform, is

ubiquitous in the modern operations center or vehicle system. Most Soldiers now use one as a component of a COP. While few may understand it, those who do, recognize it as a vital link between physical relationships in the OE and rationalized knowledge about those relationships. Tools of representation serve as a bridge between information and intelligence, knowledge, or reason. The COP serves as a tool to enhance this process. The Army has numerous tools to assist with visualization, which most Soldiers use regularly.

The final component, reason, is the realm where spatial thinking enhances military operations. Reason is arguably the intent behind problem solving. Carried through, IPB provides reason to individual bits of information gathered as part of the first step. If present, the output of this component is an example of where the Army maximizes the third component. As with the first component, it is difficult to gage how much of IPB problem solving comes from spatial thinking. However, it is logical to deduce that generating reason requires knowledge, training, and dedication. Some Army actions enable this, such as UVD, land navigation, and the geospatial sciences. As has been presented in this chapter, the Army is lacking in definition, instruction, and advocacy to enable structured and informed spatial reasoning skills. Based on these factors, the third component is an area where the Army may not be maximizing its ability.

Returning to Webster's definition of maximization, this indicates that the Army is not necessarily getting the best result due to a weakness with spatial reasoning. The lost opportunity is that the Army is inconsistently generating new reason out of the spatial thinking process. Structurally, the Army creates spatial reason through geospatial professionals. Functionally, every Soldier should be able to think spatially about the OE.

This can be likened with an ability to think critically. Over the past decade the Army recognized the utility in fostering an inquiring mindset in its Soldiers. Critical thinking is leveraged every time a staff generates courses of action for a commander, and amplified because the Army defines, implements, and advocates critical thinking. Current spatial thinking utilization is more like a stove pipe, understood by those with supporting skill sets, like engineers, military geographers, or geospatial professionals. Spatial thinking is done to create new knowledge out of what is currently known. This is maximized when each of the three components of spatial thinking are used, in sequence, in order to "get the best result."

Summary

The analysis in this chapter used content analysis to compare academia's and the Army's use of spatial thinking through definitions, instruction, advocacy and maximization to answer the primary research question. What are the lost opportunities for the U.S. Army if doctrine does not utilize spatial thinking to help describe a complex operating environment?

How does the Army define spatial thinking? The U.S. Army lacks a clear definition of spatial thinking in any of its doctrinal sources, and represents a lost opportunity. While the wording may not be present, the closest Army relationship between the academic definition of spatial thinking lays within the Mission Command process. As part of his/her support to operations, commanders must be able to understand, visualize, and describe how forces relate within an operating environment. It is this UVD process that closely mirrors the academic definition of spatial thinking; conceptualizing space, representing spatial interactions, and using reason to create meaning.

How does the Army instruct spatial thinking? The Army does not formally instruct spatial thinking, and represents a lost opportunity. It does, however, instruct technical tasks that enable a Soldier to increase his/her spatial abilities. Some of these tasks include land navigation and IPB. What is lacking in the Army that is present in academia are structured classes and courses that delve into the cognitive function of spatial thinking. The presence of tasks which promote spatial thinking ability is a good baseline, onto which the Army can adopt academia's blueprint for instructional classes.

How does the Army advocate for spatial thinking? The Army lacks an established advocate (proponent) for the furthering of spatial thinking, representing a third lost opportunity. Some of this may stem from the debate between the Military Intelligence Corps and the Corps of Engineers as to who controls spatial information. Since spatial thinking is a mode of thought, not a product or dataset, its utility stretches beyond two single branches or functions. A single advocate serves to unify effort, not to claim ownership of its enabling functions. Potentially, an advocate for spatial thinking could be the Army Geospatial Center.

How does Army maximize spatial thinking? The Army focuses on the first two components of spatial thinking; knowledge and representation. Before starting a new mission or entering a new OE, the Army structurally gathers information to understand the physical components of the space around a unit. The Army uses tools of representation to create a common basis for situational understanding across a force based on that information. This is best embodied by a common operating picture which leverages geospatial software and detailed data to render a visualized operating environment. While these are powerful components of spatial thinking, they are two-

thirds of the equation. Maximizing input knowledge and visualization alone cannot lead to understanding of the spatial nature of an OE in order to generate reason. By not understanding, and thus not universally leveraging, the third component of spatial thinking, the Army cannot maximize spatial thinking as a mode of thought. Using the answers to these four questions, it is possible to draw conclusions about the lost opportunities identified by a divide between Army and academic thought on spatial thinking.

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[1] Department of the Army, ADRP 1-02, 1–42.

[2] Ibid., 1–6.

[3] U.S. National Research Council, *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum,* ix.

[4] Merriam-Webster, "Spatial," accessed 13 April 2016, http://www.merriam-webster.com/dictionary/spatial.

[5] Jerry Jindrich, "Spatial Concepts," 2013, accessed 30 January 2016, http://www.meddybemps.com/SpatialConcepts/.

[6] Merriam-Webster, "Distance," accessed 20 February 2016, http://www.merriam-webster.com/dictionary/distance.

[7] Department of the Army, Field Manual (FM) 3-25.6, *Map Reading and Land Navigation,* (Washington, DC: Government Printing Office, 2005), 1-1 – 14-3

[8] Merriam-Webster, "Instruction," accessed 20 February 2016, http://www.merriam-webster.com/dictionary/instruction.

[9] Pennsylvania State University, "Penn State Online Courses Master of Geographic Information Systems," accessed 28 December 2015, http://www.worldcampus.psu.edu/degrees-and-certificates/geographic-information-systems-gis-masters/courses.

[10] Army Training Requirements and Resource System (ATRRS), "Spatial Thinking," accessed 13 April 2016, https://www.atrrs.army.mil/.

[11] Ibid.

[12] ATRRS, “Course 4N-125D,” accessed 13 April 2016, https://www.atrrs.army.mil/.

[13] U.S. National Research Council, *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, 8.

[14] Department of the Army, ATP 2-01.3, 1–2.

[15] Ibid., 1–2 to 1–3.

[16] Stromberg, “Is GPS Ruining Our Ability to Navigate for Ourselves?”

[17] Merriam-Webster, “Advocate,” accessed 4 March, 2016, http://www.merriam-webster.com/dictionary/advocate.

[18] U.S. National Research Council, *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, iv–vii.

[19]Miller, “Beyond the Nobel.”

[20] Merriam-Webster, “Maximize,” accessed 24 February, 2016, http://www.merriam-webster.com/dictionary/maximize.

[21] Figal, “Spatial Thinking,” 339.

[22] U.S. National Research Council, *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, 2–3.

[23] Ibid., 8.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study began by posing the research question: What are the lost opportunities for the U.S. Army if doctrine does not utilize spatial thinking to help describe a complex operating environment? This question originates from an increase in missions which the Army is called upon to solve, and the corresponding complexities that those missions bring with them. From "Strategic Landpower," Generals Odierno and Amos and Admiral McRaven implore future leaders to better understand the intricacies of the environment's impact on military operations.[1] This implies that somehow the Army is not ready, not capable, or not good at understanding these intricacies.

In the introduction, spatial thinking was posed as an enabling mode of thought to help assist with dissecting complex environments. Throughout history, great commander's such as Scipio, Caesar, Charlemagne, Napoleon, and Lee were able "to look over a battlefield, to take in at first instance the advantages and disadvantages."[2] There is something about great leaders that enabled, and will continue to enable, them to envision a battlefield differently. Spatial thinking was posed as one component to this explanation. It is currently embodied as a commander's ability to understand, visualize, and describe operating environments within Mission Command.

Academic literature introduced spatial thinking through its roots in philosophy, geography, and psychology. The National Research Council published a seminal volume on spatial thinking in education. In this the NRC defined spatial thinking and provided background on its importance to research and problem solving. Of importance is the idea

that spatial thinking is composed of three parts, understanding space, representing space through tools, and generating new reason from them.[3] Additionally, it is kinesthetic, meaning that spatial thinking cannot be learned without interaction and practice in the physical world.[4]

Through content analysis, it appears that the Army is missing an opportunity to use spatial thinking, as academia has, to assist with problem solving. Spatial thinking equips Soldiers with a mode of thinking that assists with understanding interrelationships in an operating environment, and how the Army is impacted by them. Academia provides one model for how the integration of spatial thinking helps with scientific problem solving. The Army must create its own model, but should at least define, implement, advocate, and maximize the use of spatial thinking.

Definitions and descriptions matter. How the military, academia, and society frame a problem impact how they are addressed and solved. The Army lacks a clear definition of spatial thinking. Its relative, the ability of a commander and staff to understand, visualize, and describe an operating environment, replicates the intent but not the impact of spatial thinking. By not clearly defining spatial thinking, the Army misses an opportunity. The lost opportunity of not closing the definition gap would mean that the Army lacks a common language to describe the spatial components of an OE.

Academia has a multitude of spatial thinking courses and curricula. The Army has many technical tasks that help to enable spatial thinking skills. The lost opportunity here is greater than that of a definition, since it strikes at the heart of ability–instruction. By not teaching spatial thinking the Army runs a risk of not equipping Soldiers with the cognitive skills required to solve complex problems. Generals Odierno and Amos and

Admiral McRaven implore leaders to better understand complex environments, specifically human interactions in those environments. If the Army does not teach Soldiers how to think about the spatial component of problems, then their future ability to understand OE interactions is handicapped.

Academia and the Army each lack a spatial thinking advocate. The lack of an advocate is a lost opportunity to unify the effort, knowledge, and capabilities of spatial thinking across the force. Information becomes useful when it is connected to people and processes that can use it. An advocate agency serves this purpose, to push spatial thinking theory to Soldiers and functions that can use it to solve problems. Disjointed efforts tend to cause confusion at best, and failure at worst.

The Army utilizes one component of spatial thinking, tools of representation, to its maximum benefit–common visualization. Academia maximizes spatial thinking by using its acknowledged components to solve inter-disciplinary problems. Each use it to meet their own differing requirements. Identifying lost opportunities between the two is therefore not as useful as looking inward to the Army to see if it is creating its own loss by not maximizing capabilities. Doing this reveals that the Army is ignorant of, and thus not able to maximize, the reason (description) component of spatial thinking. The lost opportunity here is the greatest because spatial thinking requires all three components. Humans cannot fully understand spatial interactions in the world around them without using all elements.

Recommendations

The Army should clearly define spatial thinking, just as it did with critical and creative thinking. Spatial thinking is a complementary mode of thought to critical,

creative, and systems thinking. It enables one to look at problems in different ways, breaking up the whole into smaller parts. The Army clearly defines the other modes of thought within doctrine. A recommended definition, based on this research, is that "spatial thinking is a thought process that utilizes spatial relationships to understand, represent, and generate knowledge about an operating environment." Including spatial thinking into current doctrine is one small, measurable step to rectifying an opportunity that could leave future Soldiers mentally unprepared to understand the complexities of the world around them.

With a clear definition in doctrine the Army can implement spatial thinking through formal programs of instruction. Similar to the adoption of critical thinking in many Army professional military education programs, spatial thinking has the potential to boost Soldiers' understanding of how they address problems. Solving difficult military problems, essentially the art of strategy, is of paramount importance to the security of this nation.

The Army needs to identify a proponent Center of Excellence or training program that can serve as the advocate for spatial thinking. This would require input from nearly all branches. While the Corps of Engineers and the Military Intelligence Corps have an outsized hand in this process, it is the future ground commanders who must intimately understand spatial thinking. Napoleon's *coup d'oeuil* is branch immaterial, but cognitively enhances combat arms leaders' ability to visualize the battlefield before them. As such, there must be serious discussion and integration between the various Centers of Excellence as to the nature of spatial thinking for the entire force.

Finally, spatial thinking must be put to maximum use, covering all of its three components: understanding space, representing space with tools, and creating reasoned decisions from it that can be articulated to subordinates. Targeting and integrating all three of these components will not be easy. The Army has worked tirelessly on tools to represent space, such as Blue Force Tracker, Land Warrior, Net Warrior, and other GIS based Common Operating Pictures. As only one piece of the whole, these tools cannot convey the other two components. If a commander or staff fails to understand how the operating environment is interwoven with itself, then no tool, now or in the future, can impart understanding. Similarly, no tool can convey meaning if a commander or staff lacks the cognitive and verbal abilities to transform understanding and visualization into reason.

Arguably, the best mode for the Army to maximize spatial thinking capability, both inward to the force and outward toward the operating environment is to capitalize on the social sciences. The NRC summed up this concept the best when they recommended that:

> No matter how well designed support tools for spatial thinking might be, they will not be effective without a societal recognition of the importance of spatial thinking and an educational commitment to teaching spatial thinking to all students in all grades.[5]

By integrating and reinforcing the spatially cognitive nature of astronomy, physics, biology, geography, engineering, psychology, and others the Army can foster spatial thinking among Soldiers. These sciences all use spatial thinking to solve problems within their discipline. This leads to a greater ability to understand space, visualize environmental interactions, and describe those interactions in a meaningful way to other people. Incentivize spatially supportive disciplines so that individuals seek out degrees in

them. Encourage ROTC cadets to major in a hard science. Offer bonuses to Soldiers who will seek out this type of education. Whatever the pathway, the Army must seek out ways to maximize spatial thinking among the ranks.

Spatial thinking, while not new, is still in an adolescent age in reference to human understanding of how the brain processes spatial information. Neuroscience's explorations into the depths of the human brain will start to unlock more of that understanding. As this occurs, it is likely that more reinforcing activities will be uncovered that help train the brain. Stromberg's article summarizing the link between vehicle navigation, hippocampus growth, and spatial cognition is a good example.[6] As science finds out more about spatial thinking, the Army should endeavor to foster activities that promote spatial thinking.

For as much as the Army lacks a common and understood language of spatial thinking, it has an admirable understanding for how it should function. This is clear from the commander's required input to the operations process to understand, visualize, and describe the operating environment. It does not need to start from scratch. Rather, the Army should capitalize on the opportunity to boost Soldier knowledge. Updating doctrine to include spatial thinking provides a common basis for instruction. Teaching organized and structured spatial thinking lessons or courses will boost problem solving abilities. Unifying spatial thinking under an advocate allows a high bandwidth conduit between academic research and the Soldiers in the force that will use spatial thinking. Finally, recognizing and fostering spatially supportive skillsets will help to ingrain a thinking mindset.

Spatial thinking is not a panacea for overcoming complex situations. It is, however, a precept for attaining the cognitive capacities, along with critical, creative, and systems thinking, to enable military thinkers to understand operational environments. The more tools in the proverbial kit bag of knowledge, the better prepared the Army and its leaders will be to develop adequate strategies that address unique OE variables.

Future Research Opportunities

An interesting research topic would be an analysis of the correlation between great generals, spatial thinking, and their professional/educational backgrounds. This is harder in the modern U.S. military where generals are now Soldiers for life, focusing on the influence of leadership over hard sciences. Generals like Washington and Lee had extensive educational and professional backgrounds that required spatial thinking skills. It would be interesting to see if the type of academic education and/or professional career fostered abilities in great military commanders. The Army focuses on leadership capability as an indicator of greatness. Maybe greatness is historically born out of knowledge of the external world, and from there the (future) general learned the art of leadership as a method to achieve a visualized future condition.

Finally, it would be interesting to explore the four modes of thought as they relate to questioning. For example, systems thinking supports “what” and “how” questions, spatial thinking “where” and “when”, creative thinking “what” and critical thinking “why”. Just by the nature of the questions one asks, as driven by the extent of one’s ability to leverage one or more modes of thought, different solutions to the same problems may arise. If this is the case, then it is possible that focusing on the why critical thinking factor, without input from the other modes of thought, is preventing Soldiers

from truly synthesizing the why. The answer to why should be informed by the "who, what, where, when, and how." Asking those questions may be the human way to manifest the other modes of thought to understand a problem.

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[1] Odierno, Amos, and McRaven, "Strategic Landpower: Winning the Clash of Wills," 3.

[2] Heinl, *Dictionary of Military and Naval Quotations*, 70.

[3] U.S. National Research Council, *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, ix.

[4] Figal, "Spatial Thinking," 339.

[5] National Research Council, *Learning to Think Spatially: GIS as a Support System in the K-12 Curriculum*, 232.

[6] Stromberg, "Is GPS Ruining Our Ability to Navigate for Ourselves?"

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